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(54) **TWO-PATH HYDROMECHANICAL TRANSMISSION AND CONTROL METHOD THEREFOR.**

(57) This invention relates to a two-path hydromechanical transmission mounted on the cat-erpillar vehicle or the like and to a method of controlling the same, in which excellent operability and straight advancement performance can be obtained in a low speed zone and a high efficiency of power transmission is possible even in a high speed zone, using a small-capacity hydraulic pump and hydraulic motor. For attaining the above effects, the transmission is composed of: hydraulic pumps (2), (3) disposed independent from each other on the right and left sides and driven by an engine and hydraulic motors (4), (5) disposed in the same way as above;

a power transmission path provided with reduction gear trains (100), (159) for transmitting output torque from the motors to the driving wheels and planetary reduction gear trains (200), (250); and another power transmission path provided with a reduction device (300) including bevel gears for dividing output torque from the engine rightward and leftward and with the abovesaid planetary reduction gear trains (200), (250) for transmitting output torque to the driving wheels on the right and left sides. This apparatus is separately controlled for running in the low and high speed zones.

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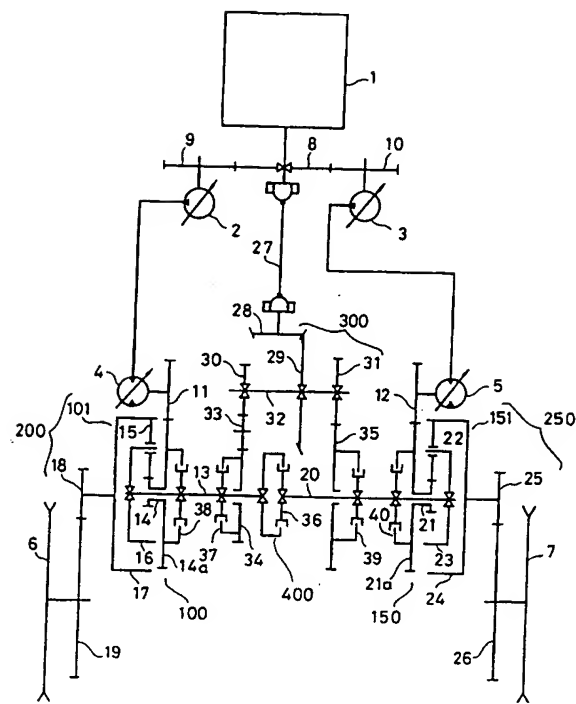


FIG. 1

TECHNICAL FIELD

The present invention relates to a speed-changing/steering system which is used on a vehicle and which has both linear speed-changing and steering functions, as well as to a method of controlling such a system. More particularly, the present invention is concerned with a 2-path hydromechanical transmission system for use in crawler-type vehicles and also to a method of controlling such a transmission system.

BACKGROUND ART

Fig. 6 shows a conventional power transmission system which is used on crawler-type vehicles such as bulldozers and which is capable of performing both linear speed change and steering. This system, known as 2-path hydrostatic transmission (referred to as 2-path HST, hereinafter) has, for the left and right crawler driving wheels 6, 7, hydraulic pumps 2, 3 driven by an engine 1, hydraulic motors 4, 5 and reduction devices 6a, 6b.

The power transmission system having such a 2-path HST, however, suffers from the following disadvantages due to the fact that all portion of the engine output torque is transmitted through the HST.

(1) Power transmission efficiency is low although the operability is superior.

(2) This type of power transmission system is difficult to apply to large-size vehicles because hydraulic pumps and hydraulic motors capable of transmitting large power are not easily available or, if available, very expensive.

(3) Straight running performance of the vehicle is affected by efficiencies of the hydraulic pumps and motors.

(4) A complicated control is required for keeping the running course of the vehicle when the control is to be done through the control of operation of the hydraulic pumps and motors.

Accordingly, an object of the present invention is to provide a 2-path hydromechanical transmission (referred to as 2-path HMT, hereinafter) which employs an HST incorporating hydraulic pumps and motors of small capacities and which exhibit high efficiency with simple construction and ease of maneuver, as well as a control method for controlling such a 2-path HMT, thereby overcoming the above-described problems of the prior art.

DISCLOSURE OF THE INVENTION

To this end, according to the present invention, there is provided a 2-path hydromechanical transmission system, comprising: a power transmission line including independent left and right hydraulic

pumps driven by an engine mounted on a vehicle and motors associated with the hydraulic pumps, and reduction planetary gear trains having reduction gear trains and differential planetary gear devices for transmitting the output torques of the hydraulic motors to left and right driving wheels of the vehicle; and an additional power transmission line including a reduction gear device having a bevel gear for distributing the output torque of the engine and forward and reverse 2nd speed clutches to which the output torque of the engine is distributed, and the reduction planetary gear trains for transmitting the output torques of the reduction gear device to the left and right driving wheels.

Left and right drive shafts to which the reduction gear trains and the reduction planetary gear trains are secured are connected to each other through a coupling device having a center clutch.

When the vehicle trams forward at a low speed, an engine mounted on the vehicle drives left and right hydraulic pumps to actuate hydraulic motors the output torques of the hydraulic motors being transmitted to left and right driving wheels via reduction gear trains and other components, whereas, when the vehicle runs in the reverse direction, the left and right hydraulic motors are reversed.

When the vehicle is steered to the left or right, the connection between left and right drive shafts to which the reduction gear trains and other components are secured is dismissed by disengagement of a center clutch in the coupling device interconnecting the drive shafts, and the operation speeds of the left and right hydraulic motors are made to differ to cause a difference in the rotation speed between the left and right driving wheels, thereby causing the vehicle to be steered.

When the vehicle trams forward at a high speed, a forward 2nd-speed clutch and the center clutch are engaged, whereas, when the vehicle trams in the reverse direction at a high speed, a reverse 2nd-speed clutch and the center clutch are engaged, and the output torque of an engine mounted on the vehicle is mechanically transmitted to planetary carriers of differential planetary gear devices through a reduction device including a bevel gear which distributes the engine output torque and forward/reverse 2nd-speed clutch to which the engine output torque is distributed by the bevel gear, and at the same time, independent left and right hydraulic pumps also are driven by the engine so as to drive associated hydraulic motors the output torques of which are transmitted to sun gears of the differential planetary gear devices via reduction gear trains, so that the driving power transmitted mechanically and the driving power transmitted hydraulically are added together at the differential planetary gear devices, whereby the

sums of the mechanically transmitted power and hydraulically transmitted power are transmitted to the left and right driving wheels.

Furthermore, according to the method of the invention, the tramming speed of the vehicle is controlled by increasing and decreasing rotation speeds of hydraulic motors driven by an engine mounted on the vehicle when the tramming speed is low, whereas, when the vehicle is accelerated during tramming at a high speed, a control is conducted such that the rotation speeds of the hydraulic motors is progressively decreased to zero and then the hydraulic motors are reversed and increase their rotation speeds in the reverse direction.

Thus, according to the invention, different modes of transmission of engine output torque to the driving wheels are selectively used according to the tramming speed: namely, a low-speed mode in which the engine output torque is transmitted to the driving wheels through an HST system, and a high-speed region in which the engine output torque is transmitted to the driving wheels both through the HST system and an HMT system which transmits the torque mechanically. In addition, left and right drive shafts for transmitting the torques to the left and right driving wheels are connected to each other at the center of the vehicle, in order to obtain a high level of steadiness or course-holding characteristic during straight running. It is therefore possible to obtain superior maneuverability and high degree of straight course steadiness during tramming at low speed, as well as high power transmission efficiency at high tramming speed, by employing hydraulic pumps and hydraulic motors of reduced capacities.

BRIEF DESCRIPTION OF THE DRAWINGS

Figs. 1, 2 and 3 are illustrations of the paths of power transmission in 2-path HMT system embodying the present invention;

Fig. 4 is a chart illustrating the relationship between rotation speed of hydraulic motor and vehicle speed;

Fig. 5 is a chart illustrating the relationship between the vehicle speed and hydraulic pressure; and

Fig. 6 is an illustration of paths of power transmission in a known 2-path HST system.

THE BEST MODE FOR CARRYING OUT THE INVENTION

A detailed description will be given of the 2-path HMT system embodying the present invention, as well as a method of controlling the same.

Referring to Fig. 1, a 2-path HMT system has two power transmission lines: namely, a first power transmission line in which output torque of an engine 1 is transmitted to left and right drive wheels 6, 7, through independent transmission lines including hydraulic pumps 2, 3, hydraulic motors 4, 5, and reduction planetary gear trains 200, 250 including reduction gear trains 100, 150 and differential planetary gears 101, 151; and a second power transmission line in which the output torque of the engine 1 is transmitted to and divided by a reduction device 300 having a bevel gear 28 and forward/backward 2-speed clutches 37, 39, the divided torque being then transmitted to the left and right driving wheels 6, 7 through the above-mentioned reduction planetary gear trains 200, 250.

Referring first to the above-mentioned first power transmission line, a left hydraulic pump 2 and a right hydraulic pump 3 are driven by a left PTO driven gear 9 and a right PTO driven gear 10 which mesh with a PTO drive gear 8 fixed to the output shaft of the engine 1. These hydraulic pumps 2 and 3 are connected, through hydraulic lines, to left and right hydraulic motors 4 and 5 which respectively drive left and right motor gears 11 and 12, respectively.

A left reduction gear train 100 is composed of the left motor gear 11 and a left sun gear 14a which idles on a left drive shaft 13 and which meshes with the left motor gear 11. The left reduction planetary gear train 200 includes: a differential planetary gear device 101 including a left sun gear 14 meshing with the left planetary gear 15, the left planetary gear 15, a left planet carrier 16 and a left ring gear 17; a left final drive gear 18 directly connected to the left ring gear 17; and a left final driven gear 19. The reduction gear train 150 and the reduction planetary gear train 250 for the right driving wheel have constructions similar to those for the left driving wheel. Namely, the reduction gear train 150 for the right driving wheel includes the right motor gear 12 and a right sun gear 21a which idles on a right drive shaft 20 and which meshes with the right motor gear 12. The reduction planetary gear train 250 for the right driving wheel includes: a differential planetary gear device 151 composed of a right sun gear 21 meshing with a right planetary gear 22, the right planetary gear 22, a right planetary carrier 23 and a right ring gear 24; a right final drive gear 25 directly connected to the right ring gear 24; and a right final driven gear 26.

The second line of power transmission will now be described. The output shaft of the engine 1 is connected through a propeller shaft 27 to a bevel pinion 28 meshing with a bevel gear 29 which is fixed to a bevel shaft 32 together with forward 2nd (referred to as F2) drive gear 30 and a reverse 2nd (referred to as R2) drive gear 31. A forward gear

train is composed of the F2 drive gear 30, an idler gear 33 meshing with the F2 drive gear 30 and an F2 driven gear 34 which idles on the left drive shaft 13 and meshes with the idle gear 33. A reverse gear train is composed of the R2 drive gear 31 and an R2 driven gear 35 which idles on the right drive shaft 20 and meshes with the R2 drive gear 31.

The left drive shaft 13 and the right drive shaft 20 are coupled to each other through a coupling device 400 having a center clutch 36 and other parts.

The F2 driven gear 34, left sun gear 14, R2 driven gear 35 and the right sun gear 21 are respectively associated with an F2 clutch 37, a left 1st speed clutch 38, an R2 clutch 39 and a right 1st speed clutch 40.

The operation of the described system is as follows.

When the vehicle trams at a low speed, e.g., at 4.2 Km/h or lower speed as viewed in Fig. 5, the left 1st speed clutch 38 and the right 1st speed clutch 40 are engaged as viewed in Fig. 2, while the F2 clutch 37 and the R2 clutch 39 are disengaged. In this state, the system functions as the HST. Consequently, the output power of the engine 1 is transmitted from the left and right hydraulic pumps 2, 3 which are controlled to maintain a constant value of the product of the delivery pressure P and the displacement V to the hydraulic motors 4, 5 and further to the left and right sun gears 14, 21 through the left and right motor gears 11, 12. In this state, the differential planetary gear devices 101 and 151 are in direct-connection state so that the rotations of the sun gears are transmitted to the planet carriers to rotate them at the same speed as the sun gears and further to the ring gears to rotate them at the same speed as the planet carriers, whereby the left and right final drive gears 18 and 25 are driven. Consequently, the speed of the vehicle is increased in proportion to the rotation speed of the motor gears of the hydraulic motors as shown by AB (forward) and AE (reverse) in Fig. 4. In order to maintain the course of the vehicle running straight, the center clutch 36 is engaged to equalize the speeds of the left and right driving wheels. The power transmission path between the propeller shaft 27 and the F2 and R2 driven gears 34, 35 via the bevel gear 29 only idles and does not make any contribution to the transmission of the power.

When the vehicle is to be steered to the left or right, the center clutch 36 is disengaged to allow the left and right drive shafts 13, 20 to rotate independently, and the rates of supply of the hydraulic fluid to the left and right hydraulic pumps 2, 3 are suitably varied to cause a change in the speed between the hydraulic motors 4 and 5, thereby effecting a gentle turn, quick turn or ultra-

quick turn of the vehicle, while maximizing the traction power of the vehicle during turning.

For a high-speed forward tramping, e.g., forward tramping at a speed higher than 4.2 Km/h as viewed in Fig. 5, the left and right 1st speed clutches 38, 40 are disengaged and the center clutch 36 and the F2 clutch 37 are engaged as viewed in Fig. 3. In this state, the system performs the function of HMT so that the output torque of the engine is transmitted from the propeller shaft 27 to the left and right drive shafts 13, 20 through the bevel gear 29, F2 drive gear 30, idle gear 33 and the F2 driven gear 34, whereby the planet carriers 16, 23 of the differential planetary gear devices 101 and 151 are mechanically driven.

The power transmitted from the left and right hydraulic pumps 2, 3 to the motor gears 11, 12 through the hydraulic motors 4, 5 drive the left and right sun gears 14, 21 so that the ring gears 17, 24 of the differential planetary gear devices 101, 151 drive the left and right final drive gears 18, 25 by the sum of the mechanical power derived from the planet carriers 16, 23 and the hydraulic power transmitted through the sun gears 14, 21. When the vehicle is to be steered to the left or right during high-speed tramping, a difference is produced between the operation speeds of the left and right hydraulic motors 4, 5 by differentiating the rates of supply of the hydraulic fluid from the left and right hydraulic pumps 2, 3.

For a high-speed reversing of the vehicle, the F2 clutch 37 is disengaged and the R2 clutch 39 is engaged so that the mechanical power is transmitted from the bevel gear 29 to the R2 driven gear 35 through the R2 drive gear 31. Operations of other parts are the same as those in forward high-speed tramping.

The vehicle speeds at high speed ranges vary along the curves BCD (forward) and the curve EFG (reverse) shown in Fig. 4. Namely, a reduction in the operation speed of the hydraulic motors 4, 5 causes a reduction in the rotation speeds of the sun gears 14, 21 but the vehicle speed increases because the rotation speeds of the ring gears 17, 24 increase in inverse proportion to the rotation speeds of the sun gears 14, 21. The speed of the hydraulic motors 4, 5 is null at the point C during forward tramping and the hydraulic motors 4, 5 start to reverse as the point C is exceeded. The speed of the hydraulic motors is then progressively increased. During reversing, hydraulic motors 4, 5 are reversed and the speed of these hydraulic motors becomes null at the point F and, thereafter, the hydraulic motors 4, 5 start to operate forward and progressively increase their speed.

As will be understood from the foregoing description, according to the invention, the vehicle is driven through HST in the low-speed range in

which delicate control is required. It is therefore possible to obtain good maneuverability equivalent to that of conventional pure HST drive vehicle. Furthermore, since the left and right output shafts are driven commonly through the coupling device, a high steadiness or course holding characteristic can be attained without being affected by the efficiencies of the hydraulic pumps and motors. In addition, the control is facilitated because there is no need for the control of the displacements of the hydraulic pumps and the hydraulic motors. Moreover, efficiency can be increased by about 10% or more as compared with the pure HST type drive system in which all the power is transmitted through an HST system alone, by virtue of the use of the HMT system in which the driving power is transmitted both through the HST system and the mechanical transmission system in the high-speed region where a large driving power is required. It is also to be pointed out that the present invention enables the capacities of the hydraulic pump and the hydraulic motor to be reduced to about half those in the known system thanks to the use of rotation of the differential planet gear device, thus offering an advantage also in the aspect of the cost. More particularly, according to the invention, it is possible to obtain an inexpensive power transmission system which can realize a high tramping speed of 8.5 Km/h or so at the maximum, by using, in combination with the mechanical driving system, hydraulic pumps and hydraulic motors of capacities which can provide, when used in a pure HST driving system, only a low tramping speed of 4 Km/h or so at the maximum.

In the described embodiment of the invention, each hydraulic pump is connected to the associated hydraulic motor through one hydraulic line. It will be clear, however, that the hydraulic pump and the hydraulic motor are actually connected to form an open circuit, semi-open circuit or a closed circuit incorporating a change-over valve or a control valve to enable the control in the same manner as that in known systems.

INDUSTRIAL APPLICABILITY

The 2-path HMT system of the present invention, as well as the control method of the same, can effectively be used as a speed-change/steering system of crawler-type vehicles.

Claims

1. A 2-path hydromechanical transmission system, comprising: a power transmission line including independent left and right hydraulic pumps 2, 3 driven by an engine 1 mounted on a vehicle and motors 4, 5 associated with said

hydraulic pumps, and reduction planetary gear trains 200, 250 having reduction gear trains 100, 150 and differential planetary gear devices 101, 151 for transmitting the output torques of said hydraulic motors to left and right driving wheels 6, 7; and an additional power transmission line including a reduction gear device 300 having a bevel gear 29 for distributing the output torque of said engine 1 and forward and reverse 2nd speed clutches 37, 39 to which the output torque of said engine is distributed, and said reduction planetary gear trains 200, 250 for transmitting the output torques of said reduction gear device 300 to said left and right driving wheels 6, 7.

2. A 2-path hydromechanical transmission system according to Claim 1, wherein left and right drive shafts 13, 20 to which said reduction gear trains 100, 150 and said reduction planetary gear trains 200, 250 are secured are connected to each other through a coupling device 400 having a center clutch 36.
3. A method of controlling a 2-path hydromechanical transmission system mounted on a vehicle, characterized in that, when said vehicle trams forward at a low speed, an engine 1 mounted on said vehicle drives left and right hydraulic pumps 2, 3 to actuate hydraulic motors 4, 5, the output torques of said hydraulic motors 4, 5 being transmitted to left and right driving wheels 6, 7 via reduction planetary gear trains 200, 250 including reduction gear trains 100, 150 and differential planetary gear devices 101, 151, whereas, when said vehicle runs in the reverse direction, said left and right hydraulic motors 4, 5 are reversed.
4. A method of controlling a 2-path hydromechanical transmission system according to Claim 3, wherein, when said vehicle is steered to the left or right during tramping at a low speed, the connection between left and right drive shafts 13, 20 to which said reduction gear trains 100, 150 and said reduction planetary gear trains 200, 250 are secured is dismissed by disengagement of a center clutch 36 in a coupling device 400 interconnecting said drive shafts, and the operation speeds of the left and right hydraulic motors 4, 5 are made to differ to cause a difference in the rotation speed between the left and right driving wheels 6, 7, thereby causing said vehicle to be steered.
5. A method of controlling a 2-path hydromechanical transmission system mounted on a vehicle, characterized in that, when said vehicle

trams forward at a high speed, a forward 2nd-speed clutch 37 and a center clutch 36 are engaged, whereas, when said vehicle trams in the reverse direction at a high speed, a reverse 2nd-speed clutch and said center clutch 36 are engaged, and the output torque of an engine 1 mounted on said vehicle is mechanically transmitted to planetary carriers 16, 23 of differential planetary gear devices 101, 151 through a reduction device 300 including a bevel gear 29 which distributes the engine output torque and forward/reverse 2ns-speed clutch 37, 39 to which the engine output torque is distributed by the bevel gear, and. at the same time, independent left and right hydraulic pumps 2, 3 also are driven by said engine 1 so as to drive associated hydraulic motors 4, 5 the output torques of which are transmitted to sun gears 14, 21 of said differential planetary gear devices 101, 151 via reduction gear trains 100, 150, so that the driving power transmitted mechanically and the driving power transmitted hydraulically are added together at said differential planetary gear devices 101, 151, whereby the sums of the mechanically transmitted power and hydraulically transmitted power are transmitted to the left and right driving wheels 6, 7.

6. A method of controlling a 2-path hydromechanical transmission system according to Claim 5, wherein, when said vehicle is steered to the left or right during tramming at a high speed, rotation speeds of said hydraulic motors 4, 5 are made to differ so as to cause a difference in the rotation speed between said left and right driving wheels 6, 7, while said clutches 36, 37 and 39 are kept in engaging states, whereby said vehicle is steered.
7. A method of controlling a 2-path hydromechanical transmission system on a vehicle, characterized in that the tramming speed of said vehicle is controlled by increasing and decreasing rotation speeds of hydraulic motors 4, 5 driven by an engine 1 mounted on said vehicle when the tramming speed is low, whereas, when said vehicle is accelerated during tramming at a high speed, a control is conducted such that the rotation speeds of said hydraulic motors is progressively decreased to zero and then said hydraulic motors are reversed and increase their rotation speeds in the reverse direction, while, when said vehicle is decelerated during tramming at a high speed, the direction and speeds of operation of said hydraulic motors 4, 5 are controlled in a manner reverse to those in the acceleration.

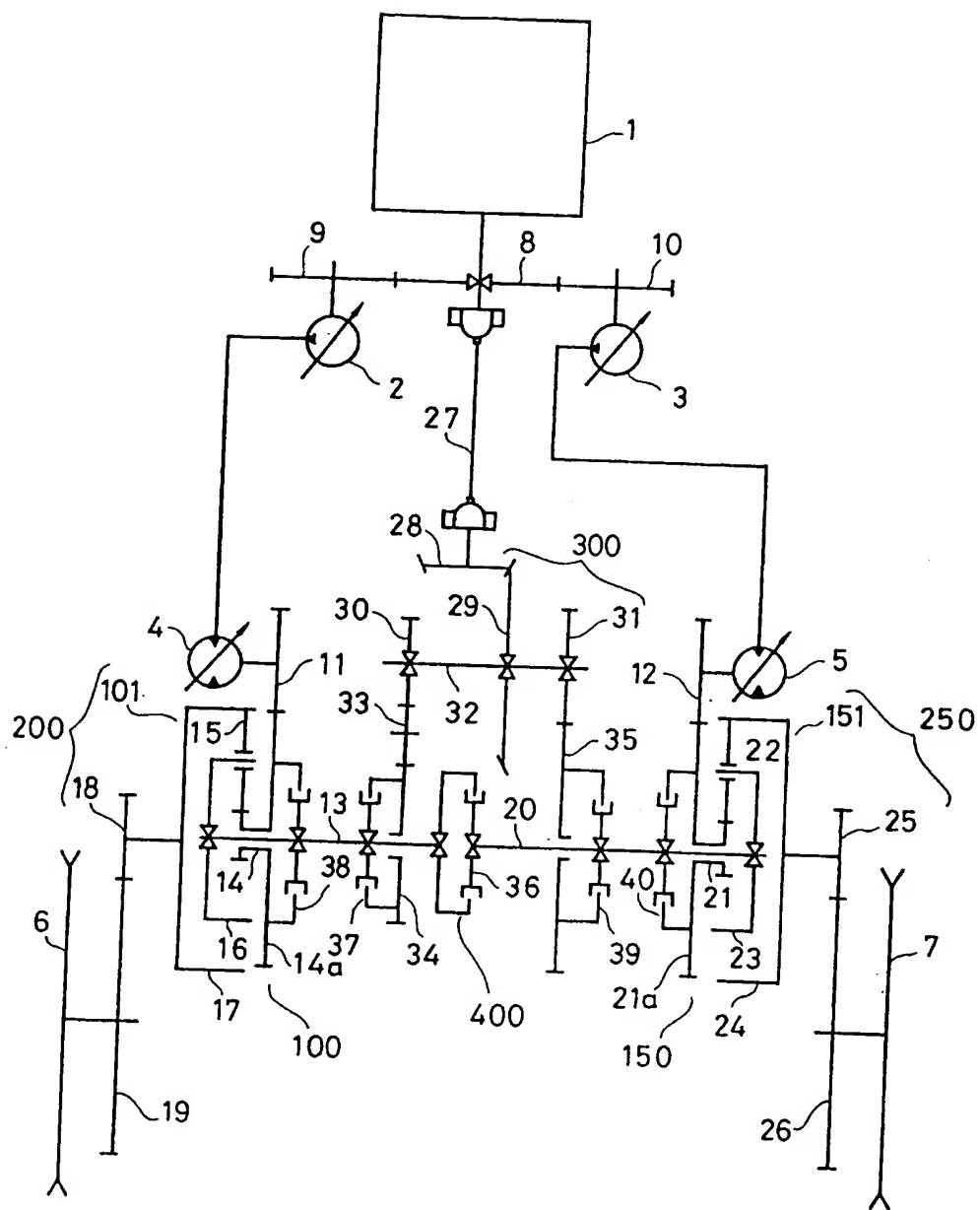


FIG. 1

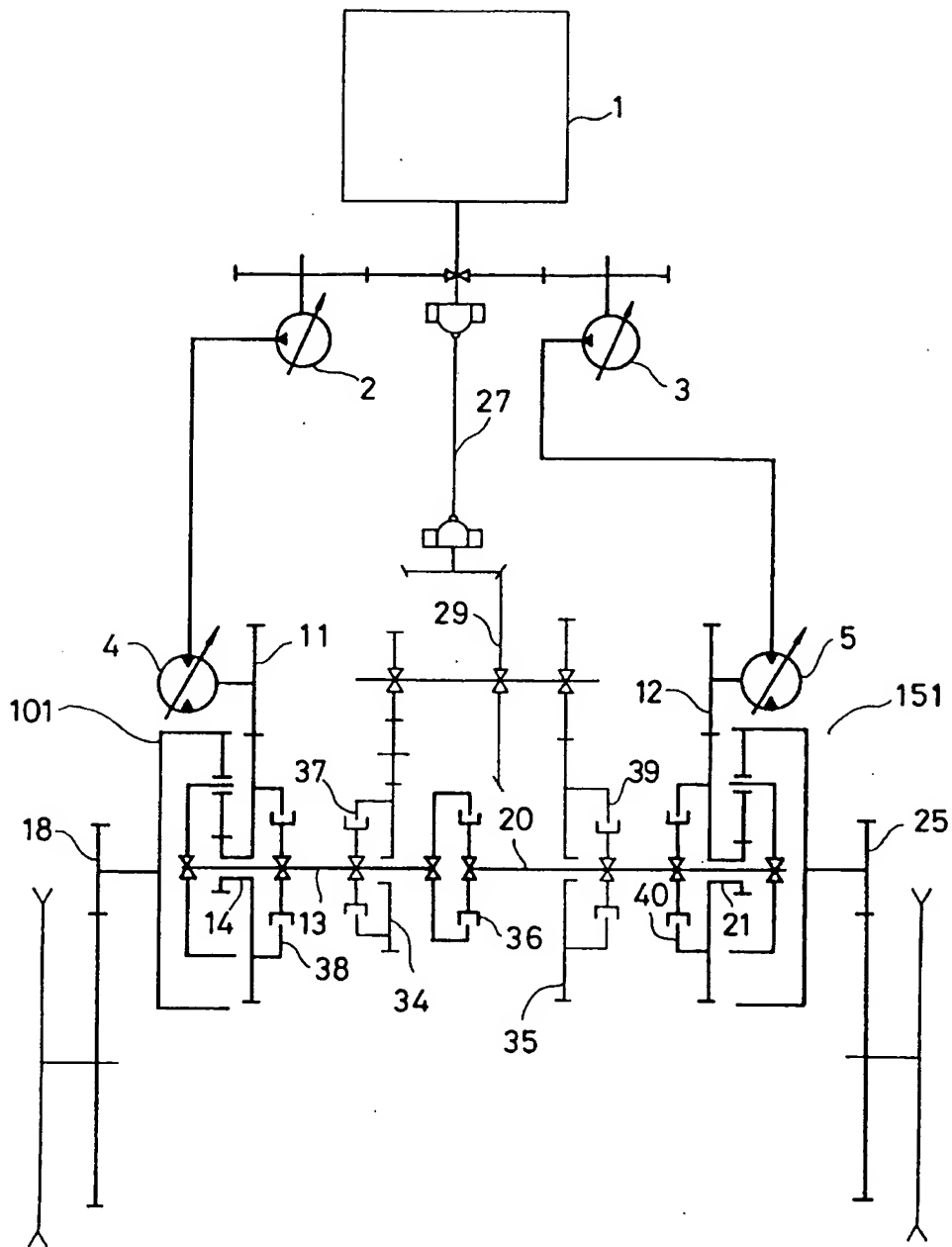


FIG. 2

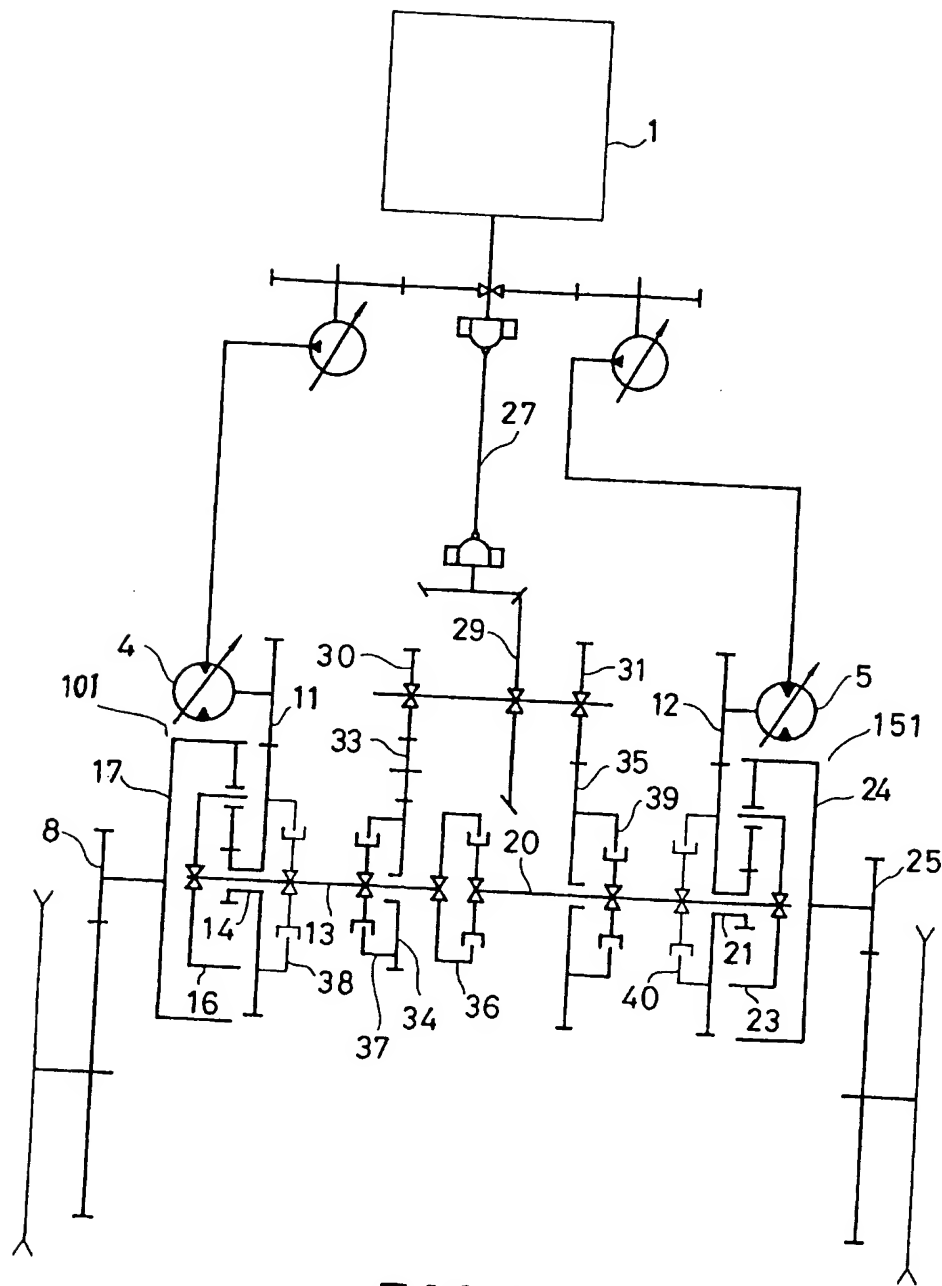


FIG. 3

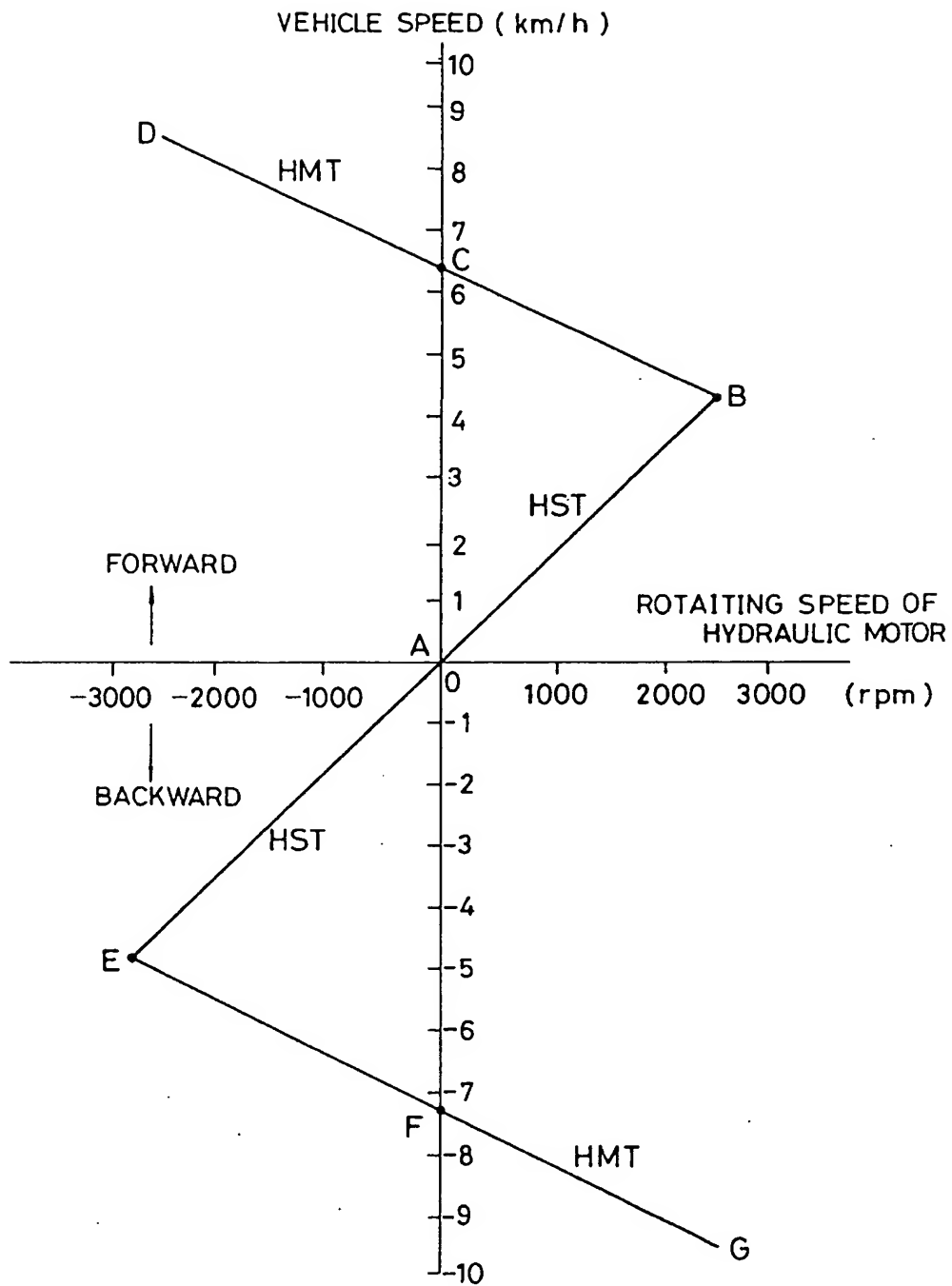


FIG. 4

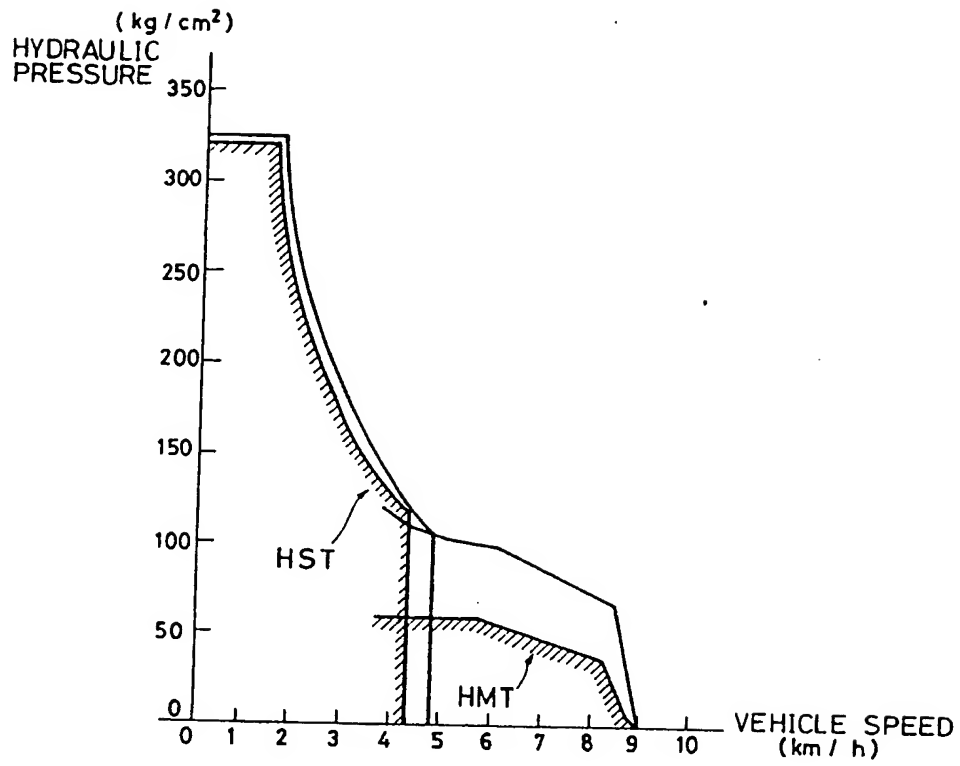


FIG. 5

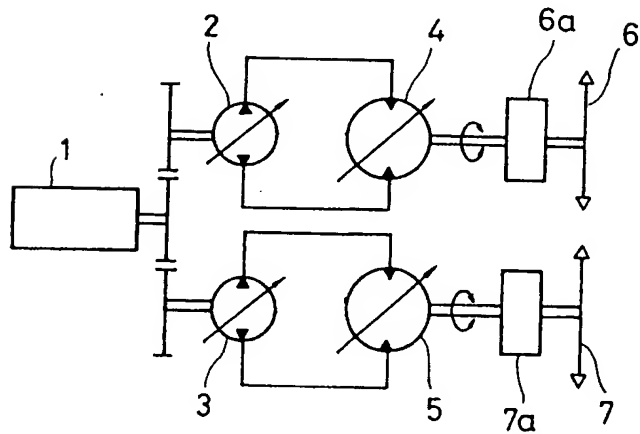


FIG. 6 (PRIOR ART)

INTERNATIONAL SEARCH REPORT

International Application No PCT/JP90/00333

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) *		
According to International Patent Classification (IPC) or to both National Classification and IPC		
Int. Cl ⁵ F16H47/02, F16H47/04, F16H61/44		
II. FIELDS SEARCHED		
Minimum Documentation Searched ⁷		
Classification System	Classification Symbols	
IPC	F16H47/02, F16H47/04, F16H61/44	
Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched ⁸		
Jitsuyo Shinan Koho	1926 - 1990	
Kokai Jitsuyo Shinan Koho	1971 - 1990	
III. DOCUMENTS CONSIDERED TO BE RELEVANT ⁹		
Category ⁹	Citation of Document, ¹¹ with indication, where appropriate, of the relevant passages ¹²	Relevant to Claim No. ¹³
Y	JP, A, 55-10174 (Dana Corporation), 24 January 1980 (24. 01. 80), Page 5, upper right column, line 17 to page 5, lower right column, line 2 and Fig. A (Family: none)	1 - 7
<p>* Special categories of cited documents: ¹⁰</p> <p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier document but published on or after the international filing date</p> <p>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p> <p>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p>"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step</p> <p>"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art</p> <p>"&" document member of the same patent family</p>		
IV. CERTIFICATION		
Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report	
March 28, 1990 (28. 03. 90)	April 9, 1990 (09 04. 90)	
International Searching Authority	Signature of Authorized Officer	
Japanese Patent Office		

